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THE UNIVERSITY OF MICHIGAN

COLLEGE OF ENGINEERING

Department of Electrical Engineering

Space Physics Research Laboratory

Semi-Annual Report

THEORETICAL AND EXPERIMENTAL INVESTIGATION OF PLASMA WAVES, SPACE VEHICLE PLASMA SHEATHS, AND IONOSPHERIC ELECTRON TEMPERATURES

Under contract with:

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RESEARCH ACTIVITIES DURING THE REPORTING PERIOD

This is the semi-annual status report under Grant No. NsG-525 covering the period from 1 October 1965 to 31 March 1966.

The calculations of the RF current response of a cylindrical probe to a normally incident plane plasma wave have been completed for the case of frequencies above, but near to, the plasma frequency. A computer program has been set up which gives the amplitude of the incident electric field as a function of the amplitude of the collected RF current, the frequency of the incident wave, the electron temperature and density in the unperturbed plasma, and probe radius and potential. Of those input parameters, the probe radius and potential are controlled by the experimenter, and the RF current amplitude and frequency are obtained from the probe. The ambient electron density and temperature can be measured simultaneously either with the same probe or with a different one mounted on the same instrument package. The theory includes the effect of Landau damping. Therefore, the Landau damping constant can also be obtained from the data on using the equation derived by us. The knowledge of this constant is of interest because it indicates the deviation of the electron velocity distribution from the Maxwellian. A sample calculation of the RF current response to an incident plasma wave for typical F-region parameters has been performed, and the signal to noise ratio was found to be of the order 10 to 1. A paper reporting the above mentioned work has been accepted for presentation to the URSI Spring Meeting in

Washington, D.C. In addition a paper based on this work will be submitted shortly to the Journal of Applied Physics. Work is in progress at the present time to extend the theory to waves of arbitrary frequency.

Work on the theory of the Langmuir probe has proceeded along two lines, a) an analysis of probe theory in the absence of a magnetic field following the approach of Bernstein and Rabinowitz[1] and b) an investigation of the effect of the magnetic field on the volt-ampere characteristics of cylindrical probes and on the density and potential distributions in the disturbed region. In the first of the two above mentioned cases (no magnetic field) the classical Langmuir theory is being extended by using more general potential distributions in the sheath region and thereby eliminating the discontinuity in the electric field at the sheath edge which is inherent in Langmuir's theory. The volt-ampere relations have been obtained in closed form for a potential distribution derived by Laframboise[2] and Self[3]. Work is in progress on the derivation of expressions for the density and potential distribution in the disturbed region. In the second investigation the effect on the probe characteristics of a time independent uniform magnetic field parallel to the cylinder axis is being studied. In the disturbed region around the probe the particles move under the influence of crossed electric and magnetic fields. Since the electric field is radial, the charged particles are subject to a rotational drift motion. In that case the logarithm of the equilibrium distribution function is a linear combination of the energy and generalized

angular momentum of the particles, as explained, for example, by Landau and Lifshitz[4]. The coefficients of this linear combination are functions of the angular velocity associated with the rotational drift motion. At the present time work is in progress to evaluate those coefficients, since they determine the electron distribution function in the disturbed region surrounding the probe.

Work on the evaluation of different Langmuir probe data reduction techniques is continuing. One method which is being considered uses the probe volt-ampere curve and its derivative with respect to the voltage. The temperature is obtained if in the "retarded" region the characteristic function is divided by its derivative. The product of function and its derivative in the "accelerated" region provides the density information. A study is under way to evaluate the requirements of a system to permit data reduction in this manner. A breadboard system has been built which uses experimental volt-ampere curves obtained during previous flights. The results of this study will be published as a University of Michigan Technical Report.

Work has been started to obtain a solution of the continuity equation for electrons in the F2 region considering varying electron and ion temperatures. This work is still in its early stages and will be reported at some later time.

The reduction of the Langmuir probe data from NASA 11.03 was completed in this reporting period. The electron temperature and density results from this flight as well as the ones from an earlier flight (NASA 8.20) were used to study the nighttime heating mechanism in the

ionosphere. We used numerical solutions of the steady state heat equation where the local heat source is one of the input parameters, and the electron and ion temperatures are calculated. The following possible heat sources were considered: (a) heat conducted down from the protonosphere, (b) electrons of kilovolt energies and (c) soft electrons of a few eV energy. A comparison of the calculated with the measured electron temperature profiles indicates that conduction was the most likely major heat source on these two occasions. These results will be presented at the COSPAR International Space Science Symposium to be held in Vienna.

The ion trap assembly with its associated electronics package is complete and ready for delivery to G.C.A. Corporation to be integrated into the Nike Apache 14-272 payload. Due to the postponement of the Puerto Rico operation, it is now planned to be launched from Wallops Island on July 20.

REFERENCES

1) I.B. Bernstein and I.N. Rabinowitz, "Theory of Electrostatic Probes in a Low-Density Plasma", Phys. Fluids 2, 112 (1959).

2) J.G. Laframboise, "Theory of Cylindrical and Spherical Langmuir Probes in a Collisionless Plasma at Rest", in Rarefied Gas Dynamics, J.H. de Leeuw, Ed., Academic Press, New York (1965).

3) S.A. Self, "Exact Solution of the Collisionless Plasma Sheath Equation", Phys. Fluids 6, 1762 (1963).

4) L.D. Landau and E.M. Lifshitz, Statistical Physics, p.11, Addison-Wesley Publishing Co., Reading, Mass. (1960).